Traumatic Brain Injury in the United States: An Epidemiologic Overview

Carl R. Summers, PhD, Brian Ivins, MS, and Karen A. Schwab, PhD

Defense and Veterans Brain Injury Center, Washington, DC

ABSTRACT

A basic description of severity and frequency is needed for planning healthcare delivery for any disease process. In the case of traumatic brain injury, severity is typically categorized into mild, moderate, and severe with information from a combination of clinical observation and self-report methodologies. Recent US civilian epidemiological findings measuring the frequency of mortality and morbidity of traumatic brain injury are presented, including demographic and etiological breakdowns of the data. Falls, motor vehicle accidents, and being struck by objects are the major etiologies of traumatic brain injury. US civilian and Army hospitalization trends are discussed and compared. Features of traumatic brain injuries from Operation Iraqi Freedom and Operation Enduring Freedom are discussed. ***Mt Sinai J Med 76:105–110, 2009.*** *© 2009 Mount Sinai School of Medicine*

Key Words: epidemiology, head injury, traumatic brain injury.

A Centers for Disease Control and Prevention analysis of hospital, emergency department (ED), and vital statistics databases estimated that about 1.4 million people presented for medical care for a traumatic brain injury (TBI) each year in the United States from 1995 through 2001.[1] The analysis also found that approximately 50,000 (3.6%) of them died from their injuries, 235,000 (17%) were hospitalized, and 1.1 million (80%) were treated and released from the ED.[1] A separate study using data about people hospitalized with TBI estimated that at the beginning of 2005, 3.17 million people in the United States (1.1% of the total population) were living with long-term disability that resulted from TBI.[2] The number of people with TBI who present in outpatient settings other than EDs, such as physicians' offices, is currently unknown as is the number of those with TBI who do not seek medial attention. However, the proportions of those with TBI who seek medical attention outside the ED or who do not seek any medical attention may be sizable. A study of data obtained from the 1991 National Health Interview Survey estimated that 25% of individuals with a self-reported TBI that resulted in loss of consciousness did not seek medical attention and that 14% were evaluated in clinics or offices.[3]

These findings reveal 2 important features of TBI. One is that it is a common injury. The other is that TBI outcomes vary greatly. They also indicate that many people who have milder forms of TBI are not identified in current databases. Studying the epidemiology of TBI is challenging for a number of reasons, including limited data sources and different methods for classifying TBI severity. However, despite these challenges, enough research has been performed about the epidemiology of TBI to identify the most common mechanisms of injury and to characterize TBI risk in various segments of the population. This article summarizes findings from epidemiological studies of TBI in the United States that provide national-level data and briefly discusses some methodological considerations that can help readers of TBI epidemiology papers understand why particular methodologies were used. A brief review of recent research findings about TBI in the US military is included.

Address Correspondence to:

Carl R. Summers
Defense and Veterans Brain Injury Center
Washington, DC
Email: Carl.Summers@amedd.army.mil

METHODS

We searched PubMed and Medline for articles published in the last 10 years that report national-level data about the epidemiology of TBI in the

Published online in Wiley InterScience (www.interscience.wiley.com).
DOI:10.1002/msj.20100

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**
4. TITLE AND SUBTITLE **Traumatic Brain Injury in the United States: An Epidemiologic Overview**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defense and Veterans Brain Injury C,Washington,DC**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

United States. Search terms included "traumatic brain injury" paired with each of the following:

- Epidemiology incidence trends (124 citations found).
- Severity classification (487 citations found).
- Symptom prevalence (78 citations found).
- Military (566 citations found).

The abstracts of publications that appeared to be relevant were then reviewed. A total of 30 publications were found and reviewed. In addition, several seminal articles from outside this timeframe were included because they established current definitions used for TBI severity[4,5] or reported seminal evidence on specific topics.[3]

INCIDENCE OF TRAUMATIC BRAIN INJURY

Overall, falls were the leading cause of TBI in the United States each year from 1995 through 2001.[1] Falls accounted for an annual average of 398,000 (28%) TBI cases during that period. Automobile crashes were the second leading cause of TBI, accounting for an average of 280,000 (20%) cases per year.[1] Being struck by or against something was the third leading cause, accounting for 19% of TBI cases annually.[1] Another common cause of TBI is assault, which accounted for 156,000 TBI cases per year.[1] A number of TBI cases do not have a known cause. These amounted to an average of 9% of all TBI cases per year from 1995 through 2001.[1]

The incidence of TBI among males is higher than it is among females. Males account for 60% of TBI cases that occur each year. Young children, older adolescents, and the elderly have the highest TBI rates.[1] Fall-related TBI among the elderly is particularly problematic. TBI accounts for 50.3% of unintentional fall deaths and 8.0% of nonfatal fall-related hospitalizations among adults over 65 in the United States.[6]

CIVILIAN TRENDS

The published literature has shown that the incidence of TBI mortality and hospitalization rates in the United States decreased in the 1980s and 1990s. TBI-related mortality in the United States, for example, declined 22.6% (from 24.6/100,000 to 19.3/100,000) from 1979 to 1992; there was an 11.4% decline (from 21.9/100,000 to 19.4/100,000) from 1989 to 1998.[7] Probable causes cited in the literature for these decreases include injury prevention efforts, compulsory safety laws (eg, seatbelt, helmet, and drunk driving laws), engineered solutions (eg, air bags), and improved treatment for alcohol and drug problems.[8]

An analysis of data from the National Hospital Discharge Survey, Thurman and Guerrero[9] found that the incidence of hospitalization associated with civilian TBI decreased 51% from 1980 to 1995 (from 199/100,00 to 98/100,000). However, most of this was due to a decrease in the incidence of hospitalizations for mild TBI. They found that hospitalizations for mild TBI decreased 61% (from 130/100,000 to 51/100,000) during that period, whereas the incidence of hospitalization associated with moderate TBI decreased 19% (from 26/100,000 to 21/100,000). The incidence of hospitalization for severe TBI increased 90% during that period (from 10/100,000 to 19/100,000).

Possible reasons for changes in TBI hospitalization rates include the following:

- Changes in hospital admission practices for mild TBI due in part to changes in health insurance coverage.[9]
- Increased survivability after severe TBI: With improved availability and quality of TBI treatment, an increasing proportion of potentially fatal TBI incidents are survivable. This is a reasonable explanation for the downward trend of TBI mortality rates with a concurrent increase in severe TBI hospitalization rates.
- Improved safety and prevention programs: Part of the decrease in both mortality and morbidity in the 1980s and 1990s may be due to injury prevention measures, especially those associated with motor vehicles[9] and motorcycle helmet laws.

However, more recent research suggests that the incidence of death due to TBI is no longer decreasing at those rates. Rutland-Brown and colleagues[10] found that the TBI mortality rate was 18.1/100,000 in 1998 and 17.9/100,000 in 2003. Data from the latest report from the Center for Disease Control also indicate that the rate of decrease in TBI hospitalizations has also leveled off.[10]

MILITARY TRENDS

The incidence of TBI-related hospitalization rates in the active-duty US Army decreased during the 1990s. The overall incidence decreased 75% (from 247.7/100,000 to 62.3/100,000) from 1990 to 1999.[11] The hospitalization rate for mild TBI in the Army

Table 1. *Glasgow Coma Scale Scoring Rubric.*

	Best Response Score					
Test	1	2	3	4	5	6
Adults						
Eyes	Does not open eyes	Opens eyes in response to painful stimuli	Opens eyes in response to voice	Opens eyes spontaneously	N/A	N/A
Verbal	Makes no sounds	Incomprehensible sounds	Utters inappropriate words	Confused, disoriented	Oriented, converses normally	N/A
Motor	Makes no movements	Extension to painful stimuli	Abnormal flexion to painful stimuli	Flexion/withdrawal to painful stimuli	Localizes painful stimuli	Obeys commands
Children						
Eyes	No eye opening	Eyes opening to pain	Eyes opening to speech	Eyes opening spontaneously	N/A	N/A
Verbal	No verbal response	Inconsolable, agitated	Inconsistently inconsolable, moaning	Cries but consolable, inappropriate interactions	Smiles, orients to sounds, follows objects, interacts	N/A
Motor	No motor response	Extension to pain (decerebrate response)	Abnormal flexion to pain for an infant	Infant withdraws from pain	Infant withdraws from touch	Infant moves spontaneously or purposefully

NOTE: This table was adapted from Teasdale and Jennett[4] and Camey *et al.*[25]
Abbreviation: N/A, not applicable.

DOI:10.1002/MSJ

decreased 78.6% (from 159/100,000 to 34.0/100,000), whereas the rate for moderate TBI decreased 57.1% (from 14.3/100,000 to 6.1/100,000), and the rate for severe TBI decreased 53.7% (from 22.8/100,000 to 10.6/100,000). A likely reason for the decrease in the Army's TBI-related hospitalization rates is a change in admission practices for mild TBI similar to those that occurred in civilian hospitals. Another possible reason is an increased emphasis on injury prevention during the 1990s.[12] Studies from the 1990s indicated that accident-related injuries in the Army decreased to record lows.[13]

A new TBI-related concern for both the military and civilian medical establishment is the influx of TBI cases due to the military involvement in the Iraq [Operation Iraqi Freedom (OIF)] and Afghanistan [Operation Enduring Freedom (OEF)] theaters of operation. These cases, including members of the National Guard and Reserve, are handled initially through the Department of Defense and Department of Veterans Affairs; however, some war-related TBI patients are likely to be seen by civilian providers. Civilian providers in some localities might see nontrivial increases in TBI cases from Reserve and National Guard combat units returning from OEF/OIF as well as OEF/OIF combat veterans who have been released from active duty and choose to be treated by private healthcare providers.

As a group, OEF/OIF TBI patients are likely to present with 2 common characteristics. The first characteristic is that the etiology of their injuries is likely to involve a blast (explosion). Gondusky and Reiter[14] reported that in their sample of a returning combat battalion, 97% of the 188 injuries sustained by 120 Marines were from improvised explosive devices (65%) or mines (32%). Using a survey of 2525 soldiers 3 to 4 months after deployment, Hoge *et al.*[15] reported that 79% of injuries reported in their survey of returned OEF/OIF veterans were from blasts. Although there is evidence that a large percentage of service members who have experienced combat-related TBI have done so because of blast wounds (frequently in combination with other causes of injury such as vehicle crashes or falls), it is not known if the TBI blast sequelae are materially different from TBI resulting only from noncombat causes such as falls and vehicle crashes. In many cases, multiple injury mechanisms are involved, and it is not possible to determine the exact cause of the TBI.

The second characteristic is that service members who are injured in combat with a TBI also have a high occurrence of posttraumatic stress disorder (PTSD) and depression. Hoge and colleagues,[15] using a sample of US Army soldiers who served in Iraq, found that 43.9% of service members that had experienced loss of consciousness (LOC) screened positive for PTSD and 24.8% screened positive for depression. Civilians with TBI have similar psychiatric comorbidities. Silver and colleagues[16] found that 11.1% of adults who screened positive for self-reported TBI also had a history of depression, but the prevalence among OIF/OEF veterans may be higher.

METHODOLOGICAL CONSIDERATIONS THAT INFLUENCE RESULTS OF TRAUMATIC BRAIN INJURY EPIDEMIOLOGY STUDIES

A variety of methods have been used to perform TBI epidemiology studies. Perhaps the most important methodological consideration faced in any type of TBI research is how to classify severity. Although TBIs are generally classified as being mild, moderate, or severe, different methods can be used to determine severity. The severity classification method that is used depends largely on the source of the data for the study. This section of the article provides a brief overview of different ways in which TBI severity can be classified and when they are likely to be used.

One commonly used method is to base severity on the Glasgow Coma Scale (GCS) score (Table 1).[4,25] The GCS score is a measure of an individual's level of consciousness. It assesses 3 domains: eye opening, motor response, and verbal response. Patients can receive a score of 1 to 4 for eye opening, 1 to 6 for motor response, and 1 to 5 for verbal response. The scores from each domain are summed to obtain the GCS score, which ranges from 3 to 15. TBI patients with a GCS score of 3 to 8 are considered to have severe TBI, those with a score of 9 to 12 are considered to have moderate TBI, and those with a score of 13 to 15 are considered to have mild TBI.

Another method is to base severity on the duration of LOC and/or posttraumatic amnesia (PTA). TBIs that result in LOC lasting 30 minutes or less and/or PTA lasting less than 24 hours are defined as mild by the American Congress of Rehabilitation, the Centers for Disease Control and Prevention, and the World Health Organization.[5,17,18] TBIs that result in LOC or PTA of longer duration are considered moderate or severe.

TBI severity can also be determined with Abbreviated Injury Scale (AIS) scores.[19] The AIS classifies injury severity into 1 of 6 categories: 1, mild; 2, moderate; 3, serious; 4, severe; 5, critical; and 6, maximal (injuries that cannot be treated). Researchers who have used AIS scores to determine TBI severity have collapsed these into the mild, moderate, and

DOI:10.1002/MSJ

Table 2. *Key Concepts.*

Approximately 1.4 million Americans are treated for traumatic brain injury annually.
Traumatic brain injury is typically categorized as mild, moderate, or severe with clinical observation (which may include imaging) and self-report methodologies.
Traumatic brain injury is a common injury that occurs most frequently in young males. Its most common etiologies are falls, motor vehicle accidents, and being struck by or against an object.
The rate of traumatic brain injury mortality and hospitalizations generally fell in the 1980s and 1990s but has leveled off since. Most of the drop in hospitalizations is in the mild traumatic brain injury range and is believed to be due, at least in part, to changes in hospital admission practices.
A developing concern for traumatic brain injury treatment is a nontrivial number of wounded Iraq/Afghanistan war veterans returning with traumatic brain injury. Members of this group are likely to have been wounded by a blast and have an elevated chance of experiencing posttraumatic stress disorder and/or depression.

severe designations that are generally used to classify TBI. When this is done, TBIs with AIS scores of 1 or 2 are considered mild, those with an AIS score of 3 are considered moderate, and those with AIS scores of 4 to 6 are considered severe.

The method used to determine TBI severity in a study is usually dictated by the source of data being used. When a researcher has access to full medical records, GCS can often be used to determine severity. When large administrative databases are used, such as the National Hospital Discharge Survey, severity can be determined with AIS scores. When data are obtained from self-report questionnaires, severity can be determined from the reported duration of LOC or PTA.

LIMITATIONS

Epidemiological research in TBI is fraught with well-documented limitations.[20–24] Definitional inconsistency, limited data, practical data collection constraints, limited resources, nontrivial numbers of injured people who do not seek treatment (resulting in an undercount), and cases of TBI being overlooked or not properly documented are the major limitations. Thus, any inferences made from these data should be made with these considerations in mind.

CONCLUSIONS

Overall TBI mortality rates in the US civilian population declined in the 1980 and 1990s but have since stabilized. TBI hospitalization rates in the US civilian population followed the same basic trajectory as mortality for the same period; however, analysis by severity shows that severe TBI incidence rates rose, moderate TBI rates were level, and mild TBI hospitalizations dropped dramatically. These trends are consistent with 3 possible scenarios: changes in admission practices for mild TBI, improvements in the delivery and care of treatment to very severe patients (who previously would have died), and improvements in safety and prevention (Table 2).

Overall US Army TBI hospitalizations dropped during the 1990s; however, unlike their civilian counterparts, a substantial decrease in TBI hospitalization was reported for all severity levels. Ivins *et al.*[11] suggested that possible reasons for the decrease were changes in hospital admission policies for mild TBI and injury prevention programs. However, it is likely that TBI hospitalizations in the Army have increased because of the wars in Iraq and Afghanistan.

The influx of troops with TBI returning from the Iraqi and Afghanistan conflicts has created a new concern for the US medical system. A large percentage of returning service members with TBI have been exposed to blasts, often in combination with other causes of injury. It is not known if there are specific sequelae caused by TBI blast exposure or if they are substantially similar to TBI sequelae resulting from noncombat causes such as falls and vehicle accidents. Additional considerations for this population include elevated rates of PTSD and depression.

ACKNOWLEDGMENT

The views expressed in the article are those of the authors and do not reflect the official policy or position of the Department of Defense or the US Government.

DISCLOSURES

Potential conflict of interest: None.

REFERENCES

1. National Center for Injury Prevention and Control. *Traumatic Brain Injury in the United States:*

Emergency Department Visits, Hospitalizations, and Deaths. Atlanta, GA: Centers for Disease Control and Prevention; 2006.
2. Zaloshnja E, Miller T, Janglois JA, Selassie AW. Prevalence of long-term disability from traumatic brain injury in the civilian population of the United States. *J Head Trauma Rehabil* 2008; 23: 394–400.
3. Sosin DM, Sniezek JE, Thurman DJ. Incidence of mild and moderate brain injury in the United States, 1991. *Brain Inj* 1996; 10: 47–54.
4. Teasdale G, Jennett B. Assessment of coma and impaired consciousness, a practical scale. *Lancet* 1974; 2: 81–84.
5. Kay T, Harrington DE, Adams R, et al. Definition of mild traumatic brain injury. *J Head Trauma Rehabil* 1993; 8: 86–87.
6. Thomas KE, Stevens JA, Sarmiento, K, Wald MM. Fall-related traumatic brain injury deaths and hospitalization among older adults–United States, 2005. *J Saf Res* 2009; 39: 269–272.
7. Adekoya N, Thurman DT, White DJ, Webb KW. Surveillance for traumatic brain injury deaths: United States, 1989–1998. *MMWR Surveill Summ* 2002; 51: 1–14.
8. Napaolitano E, Radecki J, Elovic EP. Brain injury medicine: principles and practice. In: Zasler ND, Katz DI, Zafonte RD, eds. *Brain Injury Medicine*. New York, NY: Demos Medical Publishing; 2007; 57–79.
9. Thurman D, Guerrero J. Trends in hospitalization associated with traumatic brain injury. *JAMA* 1999; 282: 954–957.
10. Rutland-Brown W, Langlois JA, Thomas KE, Yongli LX. Incidence of traumatic brain injury in the United States, 2003. *J Head Trauma Rehabil* 2006; 21: 544–548.
11. Ivins BJ, Schwab KA, Baker G, Warden DL. Moss NEG Hospital admissions associated with traumatic brain injury in the US Army during peacetime: 1990 trends. *Neuroepidemiology* 2006; 27: 154–163.
12. Brundage JF. Military preventive medicine and medical surveillance in the Post-Cold War era. *Mil Med* 1998; 163: 272–277.
13. *Army Achieves Safest Year on Record*. Washington, DC: US Army Public Affairs; 1997.
14. Gondusky JS, Reiter MP. Protecting military convoys in Iraq: an examination of battle injuries sustained by a mechanized battalion during Operation Iraqi Freedom II. *Mil Med* 2005; 170: 546–549.
15. Hoge CW, McGurk D, Thomas JL, et al. Mild traumatic brain injury in U.S. soldiers returning from Iraq. *N Engl J Med* 2008; 358: 453–463.
16. Silver JM, Kramer, R, Greenwald S, Weissman M. The association between head injuries and psychiatric disorders: findings from the New Haven NIMH Epidemiologic Catchment Area Study. *Brain Inj* 2001; 15: 935–945.
17. National Center for Injury Prevention and Control. *Report to Congress on Mild Traumatic Brain Injury in the United States: Steps To Prevent a Serious Public Health Problem*. Atlanta, GA: Centers for Disease Control and Prevention; 2006.
18. Carrol LJ, Cassidy JD, Holm L, et al. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Center Task Force on Mild Traumatic Brain Injury. *J Rehabil Med* 2004; 43():suppl): 113–125.
19. Association for the Advancement of Automotive Medicine. *Abbreviated Injury Scale, 2005*. Des Plaines, IL: Association for the Advancement of Automotive Medicine; 2005.
20. Saatman KE, Duhaime A-C, Bullock R, et al. Classification of traumatic brain injury for targeted therapies. *J Neurotrauma* 2008; 25: 719–738.
21. Thurman DJ, Coronado V, Selassie A. The epidemiology of TBI: implications for public health. In: Zasler ND, Katz DI, Zafonte RD, eds. *Brain Injury Medicine*. New York, NY: Demos Medical Publishing; 2007.
22. Setnik L, Bazarian JJ. The characteristics of patients who do not seek medical treatment for traumatic brain injury. *Brain Inj* 2007; 21: 1–9.
23. Moss NG, Wade GT. Admission after head injury: how many occur and how many are recorded. *Injury* 1996; 27: 159–161.
24. Powell JM, Ferraro JV, Dikmen SS, et al. Accuracy of mild traumatic brain injury diagnosis. *Arch Phys Med Rehabil* 2008; 89: 1550–1555.
25. Camey N, Badiatia N, Crocco TJ, et al. *Guidelines for Prehospital Management of Traumatic Brain Injury*. 2nd ed. New York, NY: Brain Trauma Foundation; 2007.